Remote Monitoring of Perforator Flaps Using an Innovative Device with an Application for Mobile Phone: A Pilot Study

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Abstract

Background Surveillance and monitoring of perforator flaps has been well established for many years as a reliable method to detect early changes in the blood flow of the flap. In this manner, early flap revisions could be performed in cases of probable thrombosis.

Methods We performed a pilot study that included the first 12 patients to use this device. A temperature sensor electrode was used for remote monitoring of perforator flaps using a mobile phone in real time via a general pocket radio service and short messages developed by the authors, allowing the surgeon to check the temperature from any location.

Results The device continually displays the temperature of the flaps in real time performing a curve with measurements every 5 minute using the web page. A significant difference ($p < 0.05$) is shown between flaps with sufficient flow and flaps with venous thrombosis.

Conclusion Real-time direct thermography via the surgeon's mobile phone is a reliable method for flap monitoring, facilitating monitorization during the time when the surgeon is away from the hospital.

Keywords
► perforator flaps
► remote monitoring
► mobile device

Surgical technique is considered the most important determining factor in the success of the flap, resulting in an overall complication rate with flap loss risk < 1%. Another important aspect to maintain a high success rate is close monitoring of the flap to identify early variations of the inflow, allowing the possibility of early anastomosis revision surgery, resulting in a more favorable prognosis.[1]

Multiple methods for flap monitoring have been implemented over time; however, clinical judgment is still the most reliable method.[2–8] Other methods used for monitoring perforator flaps are direct thermography, implantable Doppler, external Doppler, microdialysis, infrared oximetry flow, angiography, and images transmitted by electronic devices. These are but a few of the currently designed systems.[4,9–18]

The aim of this study is to report on a new device for temperature monitoring and its application for mobile telephones.

Materials and Methods

Design of the Device

The 15 × 10 × 5 cm device design is shown in ►**Fig. 1**. The blue liquid-crystal display (LCD) screen and the external characteristics are displayed. Input power transmitter and radiofrequency antenna signal can be observed. The device has an output for the temperature sensor through a 2-m long cable.

This device works through a negative temperature coefficient medical grade sensor placed on the skin flap and

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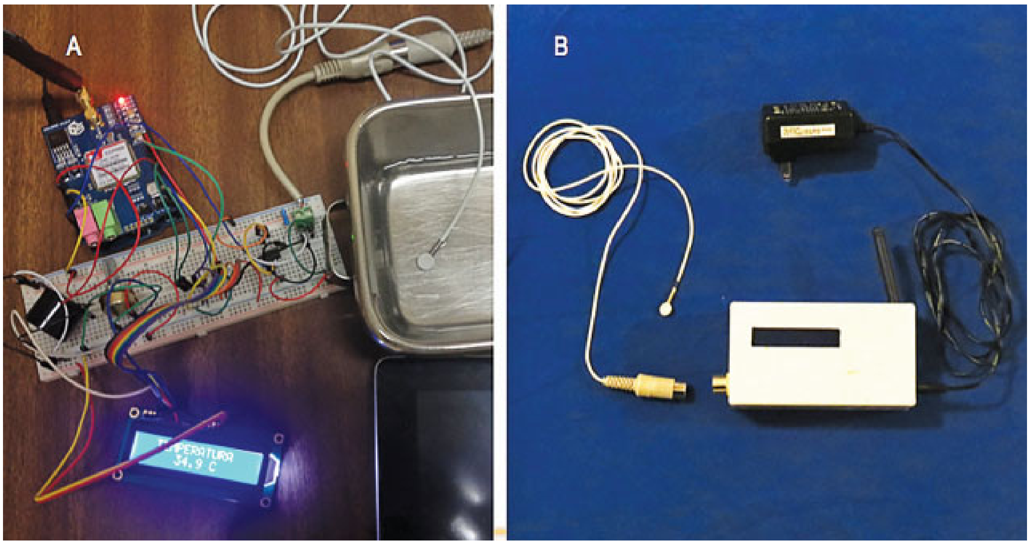

Fig. 1 (A) The ambulatory flap monitor before ensambling all the pieces. (B) The device fully finished as it looks actually.

attached with a common skin adhesive. The thermal signal is captured in the device designed by a microprocessor peripheral interface controller. The device is connected to a 16×2 character LCD display that shows temperature in real time (►**Fig. 1**).

The microprocessor uses, as a means of communication, a general pocket radio service (GPRS) modem to send data from a remote location (next to the patient's bedside) to the server and, in turn, to any mobile device (cell phone, tablet, etc.) (►**Fig. 2**). This communication between the device and server is achieved by sending data over the GPRS and short message service. The monitor is activated by software specifically designed for the device and features a range of programmable alarms according to user instructions. In our study, temperature was measured every 5 minutes and alarms were programmed at temperatures $< 36°C$.

After the perforator flap surgery and once the patient is back in the hospital room, the device with the temperature's sensor is placed directly over the flap of each patient (►**Fig. 3**). Subsequently, we accessed the web application and measures with the established temperatures parameters were initiated (every 5 minutes, alarms at $< 36°C$). Monitoring was continued during the first 48 hours after surgery and recorded in the corresponding software.

Statistical Analysis

SPSS v.10.0 (IBM Corp., Chicago, IL) for Windows was used for statistical analysis. Student *t*-test was used to compare the values of the temperature of the patient who developed venous thrombosis with the remainder of the patients. In addition, we analyzed all studied patients using a test of variance homogeneity (analysis of variance [ANOVA]); $p \leq 0.05$ was considered significant.

Results

Overall, 12 perforator flap procedures that met the selection criteria were performed from March 1 to May 31, 2015. The device was placed in all patients for temperature measurement. Data from patients were obtained from the recording sheet in the intended Web site.

Of the 12 patients, there were 4 males and 8 females; average age was 48 years ($\pm$ 14.4 years) (range: 18 – 75 years). The most frequent flap analyzed was ALT ($n = 6$) followed by deep inferior epigastric perforators ($n = 5$) and fibula with skin paddle ($n = 1$). The breast was the most common anatomic region ($n = 5$) followed by the upper limbs ($n = 2$), Achilles tendon ($n = 2$), tibia ($n = 1$), and sternum ($n = 1$).

Of the 12 patients, only 1 (patient 5) showed venous congestion 6 hours after surgery, a 42-year-old female with multiple previous surgeries in the area of the Achilles tendon. Thrombosis was reflected in the monitor with an average temperature of 35.7°C. Consequently, it was surgically explored and venous thrombosis was found in the main vessel. Thrombectomy of the pedicle artery and a new venous anastomosis were performed without complications. The remaining patients presented an above average temperature from 36.3 to 37.4°C (►**Table 1**).

Using Student *t*-test, temperature values from patient 5 were compared with the remaining patients, demonstrating a $p = 0.001$ (95% confidence interval: 0.92 – 1.05). Likewise, using a test of variance homogeneity (ANOVA), temperature results obtained for groups who showed good vascularity of the flap were compared ($n = 11, p = 0.077$). Using the above statistics (ANOVA), temperatures were compared including patient 5 ($n = 12$), obtaining a $p = 0.003$.

Fig. 2 Screen shot of a mobile phone with the web application running. We can see the temperature graph in real time.

Discussion

Perforator flaps are certainly the workhorse in most reconstructive cases that require soft tissue transfer.[16–18] Surveillance and monitoring of fasciocutaneous flaps have been well established for many years. Personal surveillance has been the most common method because it does not require input material and is easily reproducible. However, it is totally dependent on the observer's experience. Currently, the most reliable method is the use of internal Doppler probes, which are placed beside the anastomosis and continuously measure the flow.[2–13,19] However, this method is not very popular in some countries such as Mexico because the cost of the device is unaffordable by most health institutions or by the patient.

Direct thermography has been well established as a reliable monitoring method and is used in many hospitals worldwide due to its low cost and easy interpretation. Our device is based on a receiver electrode with a porcelain covering that isolates room temperature and, in turn, sends the temperatures taken by the device in real time to the surgeon's mobile device. This is done every 5 minutes and

Fig. 3 The device applied to a patient with a deep inferior epigastric artery perforator flap for breast reconstruction.

sent to the cell phone. In this way, the surgeon checks the temperature from any location.

Another advantage of the device is the alert system via text message, which sends it automatically in case it records temperatures < 36°C. Interpreting our results, it appears there are significant differences in the temperature of flaps that remained well perfused with those that presented venous thrombosis (patient 5, $p = 0.0001$). Similarly, no difference was observed in terms of temperature records of patients with good flow ($p = 0.077$) according to the test of homogeneity of variance of all patients. However, including the patient with venous thrombosis (patient 5), a difference is observed in homogeneity of variance with a $p = 0.003$. These results show that the temperatures measured with the designed device are statistically different in patients with good vascular flow as opposed to the patient with venous congestion and secondary thrombosis.

Table 1 Temperatures taken by the device in the patients who participate in the study

Patient no.	Flap	Minimum	Maximum	Average	Standard deviation
1	ALT	34.8	37.3	36.73	0.37
2	ALT	36.3	37.3	36.79	0.24
3	DIEP	36.5	37	36.69	0.1
4	DIEP	35.8	37	36.29	0.3
5	ALT	35.2	36.8	35.7	0.19
6	DIEP	36	36.9	36.54	0.26
7	Fibula	36	37.2	36.6	0.21
8	ALT	36.5	37.4	36.82	0.21
9	ALT	36.2	37.3	36.73	0.21
10	ALT	36.1	36.6	36.42	0.1
11	DIEP	36	36.5	36.3	0.13
12	DIEP	36	37	36.67	0.19

Abbreviations: ALT, anterolateral thigh; DIEP, deep inferior epigastric perforators.

Conclusion

Real-time direct thermography via the surgeon's mobile phone is a reliable method for flap monitorization, facilitating the procedure even when the surgeon is away from the hospital.

Conflict of Interest

None.

Acknowledgments

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